NAME DATE STARTED TARGET END DATE

GCE A LEVEL — COMPUTER SCIENCE UNIT 4 QUESTION PACK

1500U40-1 · 2015 spec Unit 4 Topic 1 · A2 unit, first sat 2017, 100 marks, 2h paper

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COMPUTER SCIENCE — UNIT 4 · CPU Architecture, Buses & Assembly Programming

Topic 4.1 — CPU components, the fetch-execute cycle, system buses and writing assembly-language programs

Describing the role of CPU components (ALU, CU, registers, accumulator), the buses involved in the fetch-execute cycle, the sequence of operations using PC / MAR / MDR, and writing short assembly-language programs against a given instruction set to solve real control problems (counting, code-matching, weight-checking, electronic locks).

2015 specification · current

Estimated time for entire question pack: ~1 h 52 min

Derived from the Unit 4 pace of ~1.5 min/mark, padded for written-prose answers (75 marks over 8 questions).

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive topic question pack**, not a single mock paper. It contains every question from the WJEC A2 Unit 4 papers (Summer 2017 – Summer 2024, COVID gap) that maps onto Topic 4.1 of the 2015 specification.

Questions are ordered by source paper date.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working. A calculator is allowed where useful.

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Q	Source	Max	Mark
1	S17 Q3	9	
2	S18 Q1	14	
3	S18 Q2	9	
4	S19 Q5	10	

Q	Source	Max	Mark
5	S22 Q3	12	
6	S23 Q3	9	
7	S24 Q1	6	
8	S24 Q7	6	
Total		**75**	

CPU Architecture, Buses & Assembly Programming — what the spec asks

WJEC GCE A Level Computer Science (from 2015) · Unit 4: Computer Architecture, Data, Communication & Applications · Topic 4.1.

Main CPU components

- ALU: performs arithmetic and logical operations on operands held in registers.
- Control Unit: decodes instructions and orchestrates the timing of fetch/execute steps.
- Registers: small, very fast storage inside the CPU (PC, MAR, MDR, IR, accumulator).
- Cache: small high-speed buffer between CPU and main memory to hide latency.

System buses

- Address bus: one-way, carries the memory address from CPU to memory.
- Data bus: bidirectional, carries the actual data/instruction word.
- Control bus: carries timing/control signals such as READ, WRITE, interrupt.
- Wider buses ⇒ more data per cycle ⇒ higher throughput.

Fetch–execute cycle

- Fetch: PC ⇒ MAR, memory[MAR] ⇒ MDR ⇒ IR; PC++.
- Decode: CU interprets IR to find operation + operands.
- Execute: ALU/registers carry out the action, write back if needed.
- Loop forever; interrupts checked between cycles.

Assembly language commands

- LDA / LOD / IN: load a value or register.
- ADD, SUB, INC, DEC: arithmetic on the accumulator or named register.
- STA / MOV: store/copy values between memory and registers.
- JMP, JGT, JZE, JNG: unconditional and conditional jumps to labels.

Writing an assembly program

- Translate each line of the high-level / pseudocode algorithm individually.
- Track the value in the accumulator between every instruction.
- Use labels for loop tops; conditional jumps for IF and UNTIL/WHILE.
- Comment each line in pseudo-form so the marker can follow your logic.

Common assembly idioms

- Counter: load 0; loop body; INC; compare-and-jump while less than target.
- Compare two locations: LDA A; SUB B; JZE EQUAL.
- Output through a dedicated OUT instruction with the value in the accumulator.
- Always end with HLT (or an explicit stop label) if the spec requires.

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Crib sheet »

CPU Architecture, Buses & Assembly Programming in one page

Quick-reference notes — revisit before each question.

Fetch cycle

PC → MAR
memory[MAR] → MDR → IR
PC ← PC + 1
Then decode & execute.

Buses

Address bus: CPU→mem (1-way).
Data bus: bidirectional payload.
Control bus: READ / WRITE / IRQ / clock.

CPU components

ALU — arithmetic & logic.
CU — decodes & sequences.
Registers — small, fast (PC, MAR, MDR, IR, acc.).
Cache — smooths memory speed gap.

Assembly idiom: count to N

```
LDA ZERO
LOOP: OUT
ADD ONE
STA COUNTER
SUB N
JLT LOOP
HLT
```

Assembly idiom: code match

IN — read keypad digit
SUB STORED — compare
JZE OK / JNZ FAIL
Output result and HLT.

Marking tips

State the value in every register after each instruction.
Comment intent in plain English.
Use a HLT at the end if your spec needs it.

3. A certain computer has an 8 bit accumulator with the following data stored in memory.

- Memory location 1A holds the number 0_{10}
- Memory location 1B holds the number 1_{10}
- Memory location 1C holds the number 9_{10}

The computer's assembly language instruction set contains the following commands.

Assembly Language Command	Description
LDA X	Load the accumulator with the contents of memory location X
JGT LABEL	Jump to LABEL if the contents of the accumulator are greater than zero
ADD X	Add the contents of memory location X to the accumulator
STA X	Copy the contents of the accumulator to memory location X
CLR	Clear the contents of the accumulator
OUT	Output the contents of the accumulator
DEC X	Decrement the accumulator by the contents of memory location X

(a) Write a simple program using only the assembly language commands above to output the integers 0_{10} to 9_{10}. [4]

(b) Two extra commands are defined as follows:

ASR R	Performs an arithmetic shift right one place on register R
LDR P, Q	Load register P with the contents of memory location Q

Demonstrate what the following fragment of code does, by showing the contents of registers and memory locations at each step. [5]

- Memory location 1D holds the number 0111 1000_2
- Memory location 1E holds the number 0100 0110_2

```
LDR R, 1D
LDR S, 1E
ASR R
LDA R
ADD S
STA R
```

4. *(a)* Explain the meaning of the term parallel processing; your answer should make reference to how parallel processing carries out a single task. [3]

(b) Give **four** limiting factors of parallel processing. [4]

5. (a) Explain the difference between truncation and rounding giving a binary example of truncation and a denary example of rounding. [4]

(b) State which method generally produces a more accurate result. [1]

(c) Describe how absolute and relative errors are calculated when truncating and rounding. [2]

6. *(a)* Convert the hexadecimal numbers -7_{16} and A_{16} into two 8 bit binary numbers, using two's complementation. Using binary addition, calculate the binary number that would result from adding them.

You must show all of your working. [4]

(b) In a certain computer system, real numbers are stored in floating point form using 16 bits as shown below.

Mantissa	**Exponent**
12 bits in two's complement form. The binary point in the mantissa is immediately after the left bit.	4 bits in two's complement form

Clearly showing your working, convert 42.875_{10} into this format. [3]

(c) In a different computer system, real numbers are stored in floating point form, an 8 bit signed mantissa and a 4 bit signed exponent.

Clearly showing your working, calculate the decimal value of $0.1111011\ 0101_2$ [3]

Answer **all** *questions.*

1. *(a)* Describe the function of two of the buses involved in the fetch-execute cycle. [4]

(b) Explain the sequence of operations that will occur during the execute phase of the fetch-execute cycle, making clear the role of the Program Counter, the Memory Address Register and the Memory Data Register. [4]

(c) An assembly language application processes the results of a laboratory experiment. A series of positive numbers is entered. A negative rogue value is used to terminate the series. The program then outputs a total and count for the data values entered.

For example:

input 6 3 7 9 -1

output 25
4

The processor has registers R, S and T. Commands available in the assembly language are:

Assembly Language Command	**Description**
LOD R, X	Load register R with the numerical value X
MOV R, S	Copy the contents of register R to register S
ADD R, S	Add the contents of register R to register S, leaving the result in register R
INC R	Add 1 to the contents of register R
DEC R	Subtract 1 from the contents of register R
JGE R, LABEL	Jump to LABEL if the contents of register R are equal to or greater than zero
JLZ R, LABEL	Jump to LABEL if the contents of register R are less than zero
JMP LABEL	Jump unconditionally to LABEL
IN R	Input a numerical value and store in register R
OUT R	Output the contents of register R

Using appropriate assembly language commands from the table above, write a program to calculate the total and count of a series of input data values, terminated by a negative rogue value. [6]

2. *(a)* (i) A programmer chooses to use a random access file system with separate overflow area to store records.

Explain what is meant by an overflow area. [2]

(ii) Another programmer recommends using the following progressive overflow strategy:

- If the memory location calculated for storing a record is already occupied, the record is stored within the main file in the next available empty location in the sequence.
- If the end of the main file is reached whilst searching for an available location, the search continues from the beginning of the main file.

Give **one** advantage and **one** disadvantage of using this progressive overflow strategy compared with a separate overflow area. [2]

(b) Daily sales records are stored in a random access file. The key field of each record consists of three letters representing the month, followed by two numbers representing the day, and two numbers representing the year, e.g. a record for 8 October 2018 would have the key field: **OCT0818**

The file has 1000 memory locations, numbered 0 - 999.

A hashing method is considered for the file:

- Take the alphabet sequence number of each letter and add them together.
- Add the day number.
- Add the year number.
- Calculate the memory location using the hash function:
  total MOD 1000

For example:

MAR2418 => 13 + 1 + 18 + 24 + 18 = 74
74 MOD 1000 = 74
So the record is stored in location 74

(i) The largest number generated by this hashing method is given by NOV3099. Calculate the memory location for this date. [1]

(ii) Explain why this would be an unsuitable hashing method. [2]

(iii) Suggest an improved hashing method for storing records with key fields in the same format e.g. OCT0322. [2]

2. *(a)* (i) A programmer chooses to use a random access file system with separate overflow area to store records.

Explain what is meant by an overflow area. [2]

(ii) Another programmer recommends using the following progressive overflow strategy:

- If the memory location calculated for storing a record is already occupied, the record is stored within the main file in the next available empty location in the sequence.
- If the end of the main file is reached whilst searching for an available location, the search continues from the beginning of the main file.

Give **one** advantage and **one** disadvantage of using this progressive overflow strategy compared with a separate overflow area. [2]

(b) Daily sales records are stored in a random access file. The key field of each record consists of three letters representing the month, followed by two numbers representing the day, and two numbers representing the year, e.g. a record for 8 October 2018 would have the key field: **OCT0818**

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- Take the alphabet sequence number of each letter and add them together.
- Add the day number.
- Add the year number.
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For example:

MAR2418 => 13 + 1 + 18 + 24 + 18 = 74
74 MOD 1000 = 74
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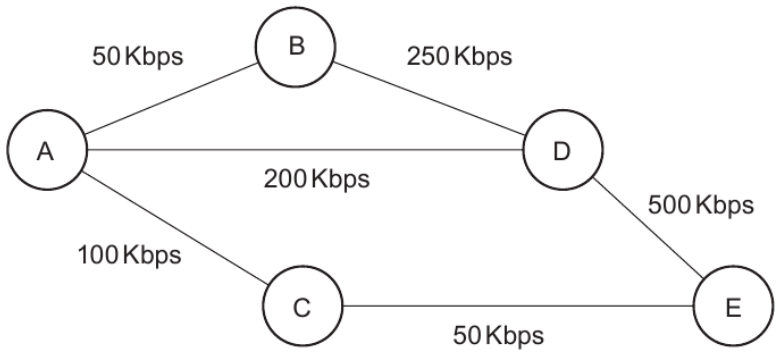
(i) The largest number generated by this hashing method is given by NOV3099. Calculate the memory location for this date. [1]

(ii) Explain why this would be an unsuitable hashing method. [2]

(iii) Suggest an improved hashing method for storing records with key fields in the same format e.g. OCT0322. [2]

3. The transmission speeds between the nodes of a network have the values shown in the diagram below.



A cost for routing data packets between nodes is calculated by dividing 1Mbps by the transmission speed of the link. For example:

$$\text{cost for the link A to B} = \frac{1\,Mbps}{50\,Kbps} = \frac{1\,000\,000}{50\,000} = 20$$

Packets are transmitted between source and destination by the route which has the lowest total cost.

(a) Calculate the costs for each of the remaining 5 links in the network. [2]

(b) Copy and complete the table below to show the routes that would be taken by packets from node A to each of the other nodes B to E. [4]

Destination node	Route, listing any intermediate nodes	Total cost
B		
C		
D		
E		

5. In a certain computer the following assembly language commands are available, where R, S, T and U are the processor registers.

Assembly Language Command	**Description**
LOD R, X	Load register R with the numerical value X
ADD R, S	Add the contents of register R to register S, leaving the result in register R
INC R	Add 1 to the contents of register R
DEC R	Subtract 1 from the contents of register R
JMP LABEL	Jump unconditionally to LABEL
JNG R, LABEL	Jump to LABEL if the contents of register R are less than zero
IN R	Input a numerical value and store in register R
OUT R	Output the contents of register R

Write a program to input a number of daily rainfall readings (in mm) for a weather station, ending with a rogue value of –1. The program should then output the total rainfall and the number of readings. [6]

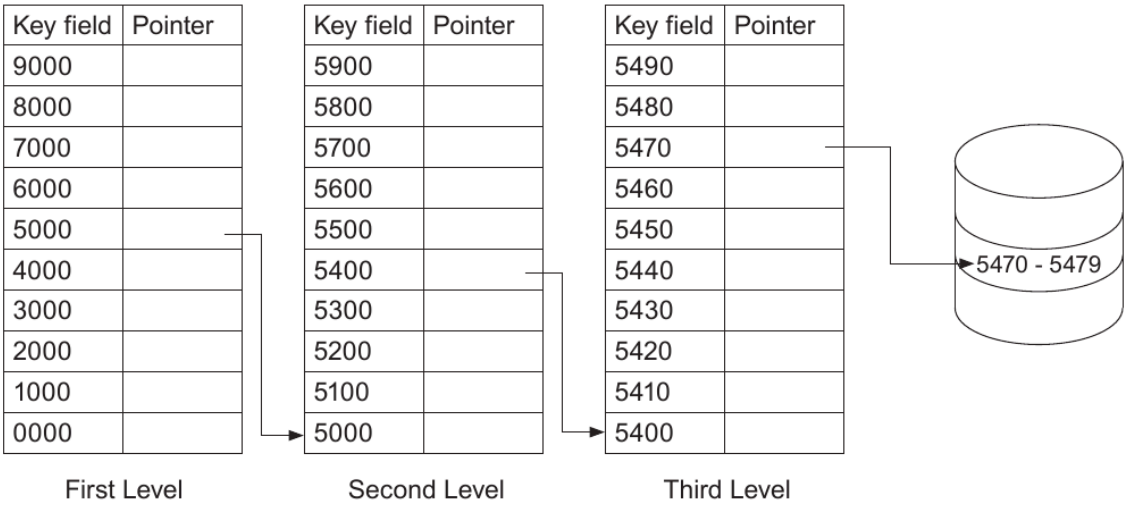
Example: input values 0 16 8 0 2 –1

output 26
5

6. A three-level indexed sequential file system stores customer records which have key field values in the range 0000 to 9999. Only a few of the possible key field values have currently been allocated to customers.

To save memory space, index blocks are only created when required. At present, only the three index blocks shown in the diagram have been created.

Customer records are stored on disk in data blocks. Each data block may contain up to 10 customer records. Records within any one data block have key field values which differ only in the last digit, e.g. 5470 to 5479, and are sorted sequentially.



(a) Explain how new customer records 3892 and 3893 are to be added to the system, mentioning the creation and linking of any necessary index or data blocks. [5]

(b) Explain how the computer would access record 3893 at a later date. [3]

7. A sequential list of English language words can be stored either in fixed length or variable length records. Six thousand (6000) words are to be stored. The maximum length of any word is 22 letters, with an average word length of 7 letters.

Variable length records have a format where each word is terminated with an @ character (which requires one byte of storage):

Estimate the sizes of the files required to store the words in:

(a) fixed length format

(b) variable length format.

Give your answers in kilobytes, correct to one decimal place. [4]

Answer **all** questions.

1. A file manager program provides an interface to a computer's file system.

(a) Describe how files may be organised and managed using a file manager program. [3]

(b) Files may be organised using a hashing algorithm. Explain the purpose of a hashing algorithm. [3]

2. Interrupts are often generated in a computer system.

(a) Identify a situation in which a high-priority interrupt may be generated. [1]

(b) Describe the procedure for dealing with an interrupt with a higher priority than the interrupt that is currently being processed. [3]

3. An assembly language program is required to check a four digit numeric code against a code stored in location Y.

If the code is entered correctly then the program should output 1. If the code entered is incorrect the program should output 2 and should allow the user to re-enter a code.

The assembly language used by the processor has an instruction set which includes the following commands:

Assembly Language Command	**Description**
INP	Input numeric value to the accumulator
OUT X	Output a numeric value X
STA X	Copy contents of accumulator to memory location X
LDA X	Load accumulator with contents of memory location X
HLT	End
SUB Y	Subtract the numeric value in location Y from the accumulator, leaving the result in the accumulator
JZE LABEL	Jump to LABEL if the contents of the accumulator are equal to zero
JMP LABEL	Jump unconditionally to LABEL

Using the instruction set, write a program to check the code entered. [6]

4. The Internet enables the use of many communication applications. Describe the distinguishing characteristics of these communication applications:

- Podcast
- Blog
- Instant messaging
- Webcast [8]

5. A certain computer uses this 16 bit floating point representation:

Mantissa	**Exponent**
8 bits in two's complement form. The binary point in the mantissa is immediately after the leftmost bit.	8 bits in two's complement form.

(a) Convert the number 7.1875_{10} into this floating point representation. [3]

(b) Determine the most accurate representation possible for 19.3_{10} using this floating point representation. [2]

(c) Calculate the absolute and relative errors in denary for this floating point representation of 19.3_{10}. [4]

(d) Describe the relationship between the size of the mantissa and exponent in the representation of a floating point number. [3]

Answer **all** questions.

1. Giving an example for each, describe why the following applications might be preferred over keyboard entry:

(a) creating a text document by voice recognition. [2]

(b) controlling an electronic device by voice input. [2]

(c) managing a security system by voice print recognition. [2]

2. (a) A series of calculations must be carried out to complete a process:

Task 1: $a = bx + cy$

Task 2: $d = ex + f^2$

Task 3: $g = hy - d$

Explain why these tasks are **not** suitable for parallel processing. [2]

(b) A computer model is to be used to predict economic forecasts for an industrialised country. The model involves many complex calculations. It is estimated that it will take 16 hours to run on a single processor computer.

80% of the algorithm can be carried out in parallel. The remaining parts of the algorithm must be carried out serially.

Determine the time taken to run the parallel processing elements of the economic forecast model on a parallel processing system using 8 processors. [2]

3. In a food factory, packages are filled as they travel along a conveyor belt. The packages are weighed and any underweight packages are rejected.

A control program for the weighing system is to be written in assembly language. The minimum acceptable weight is stored in memory location **R**. The required algorithm is:

```
LOOP continuously
    input package weight
    subtract the value stored in location R from the input weight
    IF the remainder is zero or greater THEN
        output value 1
    ELSE
        output value 2
    ENDIF
END LOOP
```

The assembly language used by the microprocessor has an instruction set, which includes the following commands:

Assembly Language Command	Description
IN	Input a weight to the accumulator
OUT X	Output a numeric value X
ADD Y	Add the numeric value in location Y to the accumulator, leaving the result in the accumulator
SUB Y	Subtract the numeric value in location Y from the accumulator, leaving the result in the accumulator
JNG LABEL	Jump to LABEL if the contents of the accumulator are less than zero
JMP LABEL	Jump unconditionally to LABEL

Using the algorithm and instruction set, write a program in assembly language to control the weighing system. [6]

4. Giving an example for each, explain what is meant by batch processing and real time transaction processing. [8]

5. (a) Giving an example for each, describe the format of sign and magnitude and two's complement when representing negative binary integers. [4]

(b) A certain computer uses this floating point representation:

Mantissa	**Exponent**
10 bits in two's complement form. The binary point in the mantissa is immediately after the leftmost bit.	6 bits in two's complement form.

Find the base-10 (denary) number represented by the floating point value:

0110010101 000110 [2]

6. Describe the process and effects of carrying out arithmetic shifts on a two's complement negative binary number. [4]

Answer **all** questions.

1. Describe the role of three of the main components of a contemporary Central Processing Unit (CPU). [6]

2. AJ Jewellers uses a direct access file with a separate overflow area to store stock records. Each record has a key field made up from a four-digit code followed by the year number, for example: 137524, 701924.

It is proposed to use the hashing algorithm: key field MOD 1000

(a) Calculate the location of the stock records for each of the two example key fields. [2]

(b) Explain why this hashing algorithm is unsuitable. [3]

(c) Give an example of a more suitable hashing algorithm for the file. [1]

3. AJ Jewellers has invested in a 3D printing system to produce objects in precious metals. The system includes CAD software and a double buffering printer interface.

Explain why the 3D printing system uses double buffering. [4]

7. A secure display cabinet in AJ Jewellers' showroom has an electronic lock which is opened by entering a four-digit code number using a keypad.

A copy of the correct code number is stored in a computer at memory location 01A0.

The cabinet is opened when the computer sends a numeric value of –1 to the electronic lock.

A control program for the lock is to be written in assembly language. The required algorithm is:

Repeat

input a code number from the keypad

subtract the value stored in 01A0 from the input

Until the remainder is zero

output –1

The assembly language used by the computer has an instruction set, which includes the following commands:

Assembly Language Command	Description
IN	Input a numeric code from the keypad to the accumulator
OUT R	Output a numeric value R to the electronic lock
ADD N	Add the numeric value in location N to the accumulator, leaving the result in the accumulator
SUB N	Subtract the numeric value in location N from the accumulator, leaving the result in the accumulator
JMP LABEL	Jump to LABEL
JZE LABEL	Jump to LABEL if the contents of the accumulator are equal to zero

Using the given algorithm and instruction set, write a program to control the electronic lock. [6]

8. (a) Explain, using a suitable example, the difference between truncating and rounding a real number when stored as an integer in a 4-bit register. [4]

(b) Convert the hexadecimal numbers $1A_{16}$ and -14_{16} into two 8-bit binary numbers, using two's complementation. Using binary addition, calculate the binary number that would result from adding the two numbers. [4]

(c) In a certain computer system, real numbers are stored in floating point form using 16-bits as shown.

Mantissa	Exponent
12-bits in two's complement form. The binary point in the mantissa is immediately after the left bit	4-bits in two's complement form

Clearly showing your working, convert 52.875_{10} into this format. [3]

(d) In a different computer system, real numbers are stored in floating point form with an 8-bit signed mantissa and a 4-bit signed exponent.

Calculate the denary value of 00100101 0101. [3]

9. A database administrator will refer to data dictionaries and use a Database Management System (DBMS) in their work.

(a) Describe the contents of a data dictionary. [2]

(b) Explain the purpose of a DBMS. [6]

END OF QUESTION PACK

8 questions · 75 marks · ~1 h 52 min
Source: WJEC A2 Computer Science Unit 4 (1500U40-1), Summer 2017–2024, COVID gap
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